Supporting presentation for lecturers of Architecture/Civil Engineering

Chapter 03

Why stainless steels?

Introduction

Main materials used in architecture, building and construction

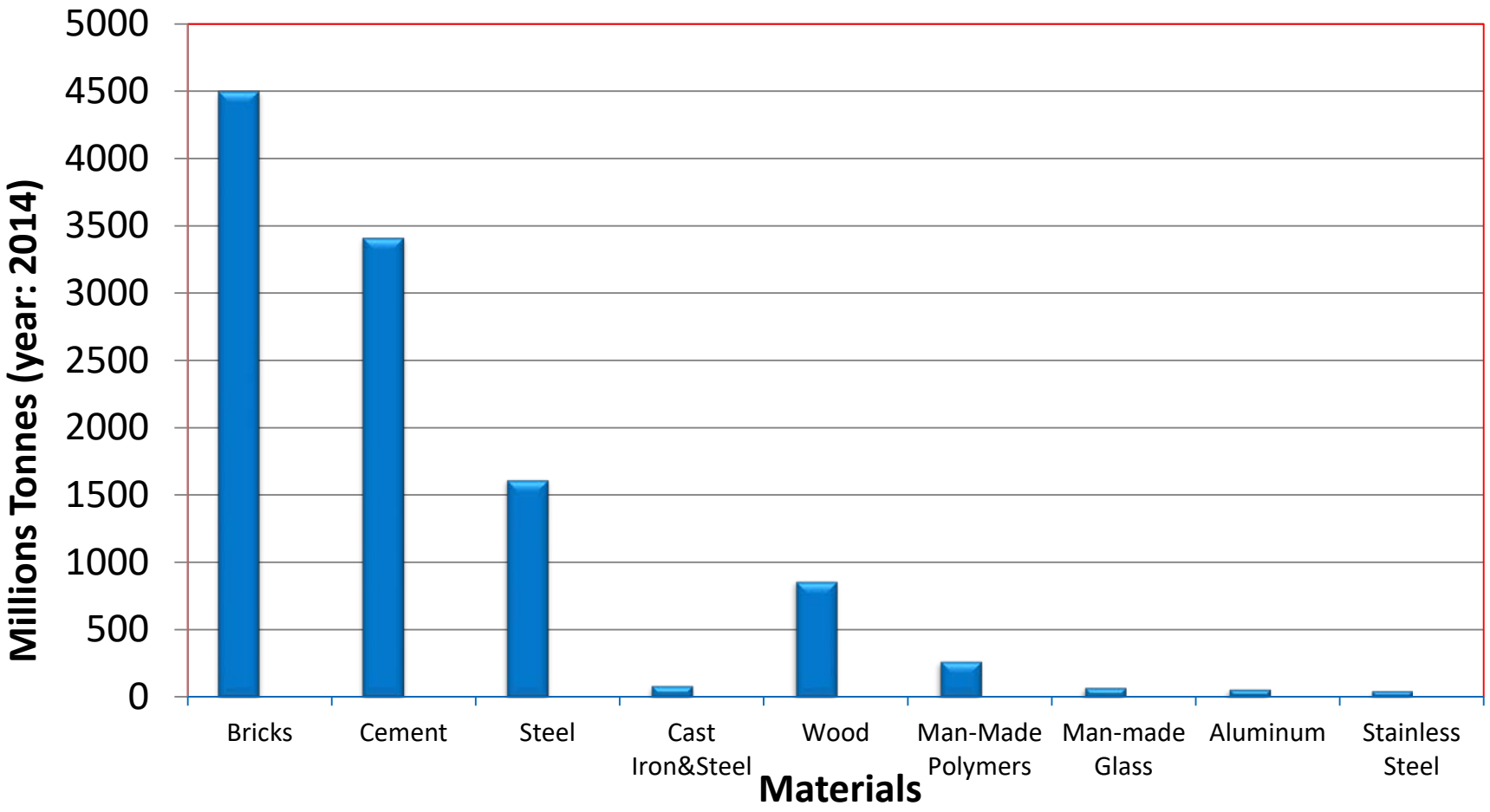
Relative use of the main building materials today

Materials	World Production 2016 *	Average Density	Remarks
Rammed earth, *pisé*	na		Was used for traditional houses in Africa mostly. Some renewed interest for its environmental properties
Bricks [2] Traditional production is very polluting and unhealthy	4500	2,0	Year believed to be 2016 Of which 87% in Asia
Cement [3]	3414	2,4**	(To obtain the figure for concrete multiply by 3-4) **Concrete density - Note: 2015 figures
Steel [4a]	1620	7,8	(Crude Steel production) 14% goes into infrastructures - half as rebar [10] 42% goes into buildings [12]
Cast Iron and Steel[4b]	85	7,8	2014 Figures Of which 48 Grey Iron, 25 Ductile Iron, 1 malleable iron, 11 steel
Wood [5] Deforestaion keeps gaining ground	868	0,56	Sawn wood+wood-based panels Excluding wood for paper (about 100) Excluding wood for combustion (about 1044)
Man-Made Polymers [6]	269	1,1	Some Natural Polymers: Cellulose, Rubber, Silk, Chitin
Man-made Glass [7]	70	2,6	Flat glass only Main other markets: Automotive, Solar energy Glass
Aluminum [8]	59	2,7	(Primary Aluminum Production) 24% goes into construction [10]
Stainless Steel [9]	46	7,8	17% goes into construction [11]

na: not available

* in Millions Metric Tons

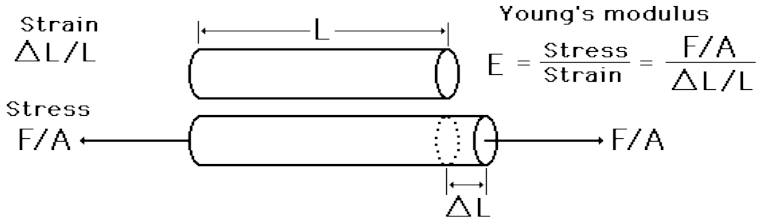
Relative use of the main building materials today: Bar Chart



Young's modulus E of various materials[12] (stiffness)

Material	Young's Modulus E (GPa)
Steels	~210
Stainless steels	~210
Copper alloys	~130
Titanium Alloys	~100
Aluminum alloys	~70
Concrete	~40
Wood	~10
Plastics	~4

Stainless steels are as stiff as steel



Strength/weight ratio[13] of architectural metals

Stainless steels offer a strength/weight ratio comparable to steels and to Al alloys

Material	Strength (YS)/Specific Weight	Yield, Stress, Mpa	Ultimate Tensile Strength, Mpa	Specific wt (Kg/dm³)	Min Elongation, %
Stainless 304 or 316, annealed	26	205	515	7,8	35
Stainless 304 or 316, work-hardened CP 350	45	350	-	7,8	-
Stainless 304 or 316, work-hardened CP 500	62	480	-	7,8	-
Duplex 2205	64	500	700/950	7,8	20
Stainless 630, aged	103	800	950/1150	7,8	10
C-steel commercial sheet, Hot rolled	30	234	317	7,8	35
Structural Steel (plate and bar)	32	250	400/550	7,8	23
HSLA Steel	49	380	460	7,8	25
Engineering Steel 4140 Q&T	96	750	930/1080	7,8	12
Aluminum Alloy 3003- H14	37	145	150	2,7	40
Aluminum Alloy 3105- H14	38	150	170	2,7	5
Aluminum Alloy 5005- H16	44	170	180	2,7	5
Aluminum Alloy 6061- T6	71	275	310	2,7	12
Aluminum Alloy 6063- T5	37	145	185	2,7	12
Copper	23	195	250	8,3	30

Simplified overview of different materials[14]

	Properties	Stainless Steels			Copper	Aluminum	Carbon Steel	Plastics
		EN 1.4521 AISI 444	EN 1.4301 AISI 304	EN 1.44O1 AISI 316				
Physical	Density	-	-	-	- -	+	-	+ +
	Linear expansion	+ +	0	0	0	-	+	- -
	Electrical Conductivity	- -	-	-	+ + +	+ +	0	- - -
	Ferromagnetism	YES	NO	NO	NO	NO	YES	NO
Mechanical	Stiffness (Young's modulus)	+ + +	+ + +	+ + +	+	-	+ + +	- - -
	Tensile	+	+ +	+ +	0	-	+ / + +	- -
	Elongation	+	+ + +	+ + +	+ + +	+ +	0	- - / + + +
Other	Fabrication	+ +	+ +	+ +	+	0	+ +	-
	High temperatures	+ +	+ +	+ + +	0	-	+	- - -
	Low temperatures	-	+ + +	+ + +	+	0	-	-
	Corrosion resistance	+ + +	+ + +	+ + + +	+ +	+	- -	+

Symbols + Advantage - Weakness (relative to the other materials)

Stainless steel remains a « young » material

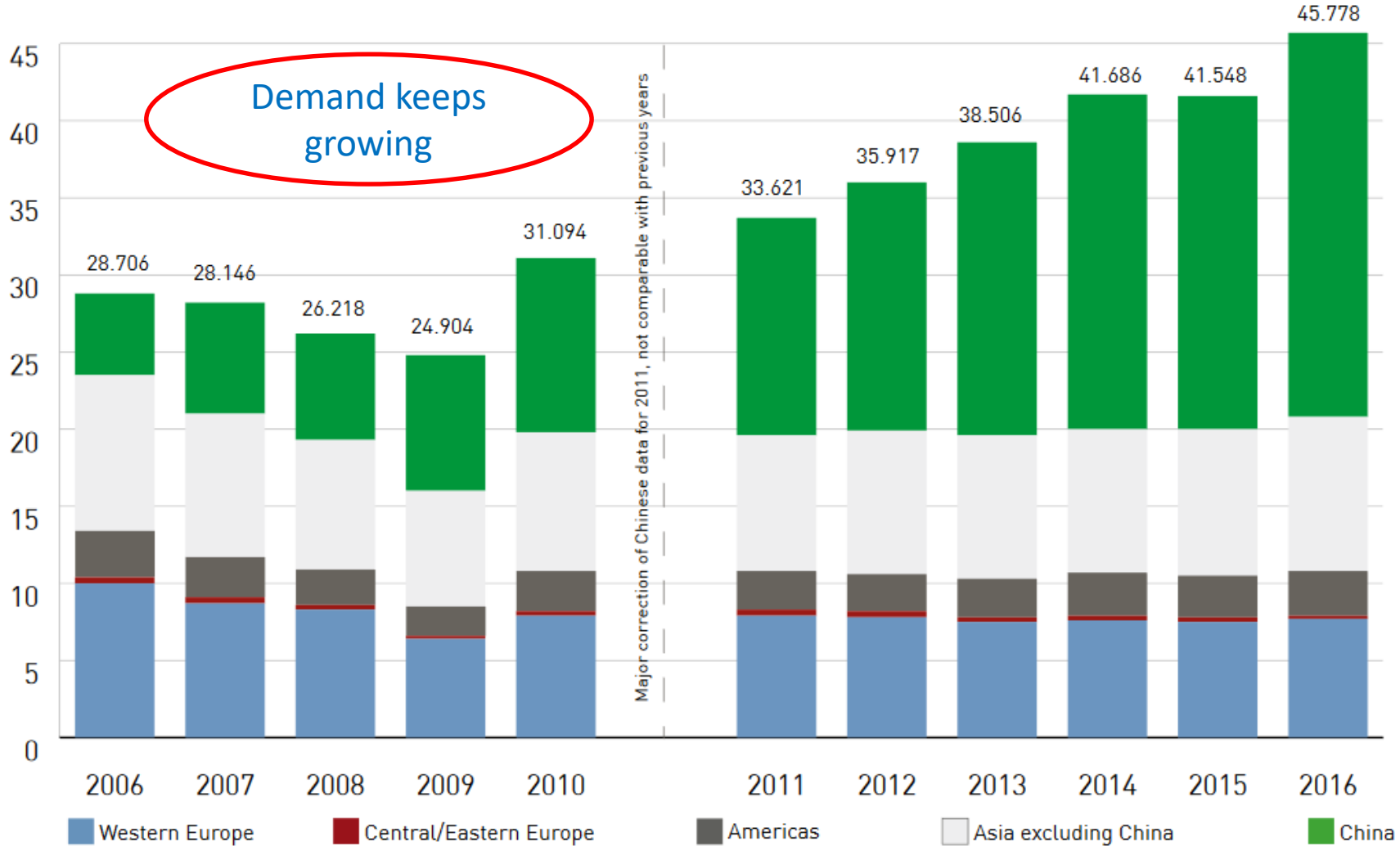
New materials have appeared in the course of history
Stainless steel is the most recent*

Materials	Timeframe	
Rammed earth, *pisé*		Has been used since the dawn of mankind!
Wood [15]		Has been used since the dawn of mankind!
Brick [15]	7500 BC 4500 BC	Fired bricks/ceramics
Steel [15]	4000 BC 1858	Blacksmiths' shops Bessemer Process
Man-made Glass [15]	3500 BC 100 BC 1950	First glassmaking Clear Glass Pilkington (Float Glass) Process
Aluminum [15]	1825 1886	Oersted discovers Aluminum The Hall –Heroult process
Reinforced Concrete [15]	1850 1885	But cement is much older Rotary Kiln Process
Man-Made Polymers [15]	1846 1907 1939	Celluloïd Bakelite Nylon
Stainless Steel [2]	1912-1913 1954 1955	Early alloys AOD Process Hot Strip Rolling

* There are newer materials, of course, but not used in significant quantities

UPDATED 2017 !

World Stainless Steel Production by area[1]



Why Stainless steel?

Because of an outstanding set of properties

1. **Corrosion resistance** (see chapter 3)
   - In all environments: tropical to polar, sea or desert, polluted or not…
   - Self-repairing, unlike coatings
2. **Lasting forever** with little or no maintenance
3. **Wide range of mechanical properties** allowed by several stainless families(Cr-Ni Austenitics – Cr-Mn Austenitics – Cr Ferritics – Duplex – Cr C Martensitics) and now built into the major building codes. Plus an excellent fire resistance (see Chapters 4 and 5)
4. **Aesthetics**: Large selection of surface finishes à colors available (see chapter 6). Plus resistance to damage in public areas
5. **Easy fabrication/joining** (see chapter 7)
6. **Excellent sustainability** (see chapter 9)
   - allows a long service life with no or little maintenance,
   - 100% recyclable (and more than 85% recycled) at the end of life into stainless steel without loss of properties
7. **Safe and Hygienic**: Inert, no contamination, easy to clean & disinfect
8. **Specific properties**: magnetic/non magnetic, ….

What limits the use of stainless steels: the price

Stainless Steels are expensive: True? Or False?

Answer: Yes and No

Yes:

If the initial material cost is all what matters (usually because of limited funding…)

But then a bad choice may be very expensive:

- Stainless steel usually represents a small part of the project
- Untimely repairs and maintenance may add huge direct and indirect costs

No:

if

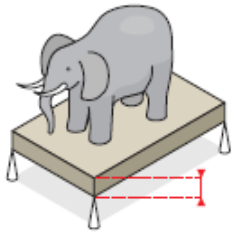
- the Life Cycle Cost (the « real » cost) is taken into account, i.e. if maintenance, service life and recycling issues are factored in*
- the design is optimized: thin sheets, profiled into complex shapes can result, in strong, stiff structures that use little material.

*The owner's best interest is always to make choices based on LCC analysis

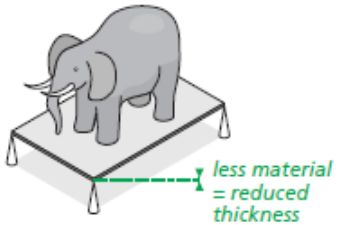
Stainless (and other metals) use less material[16]

DOING MORE WITH LESS

Due to their high strength, metals can bear high loads with less material or be used to reinforce other materials.



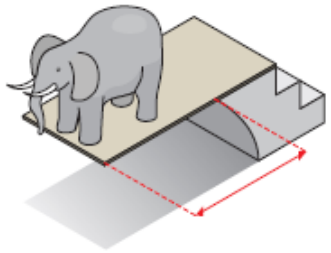
non-metallic material



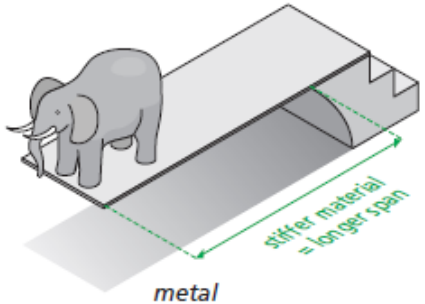
metal

FREEDOM FOR DESIGNERS

Thanks to their high stiffness, metals can span greater distances, allowing more design freedom.



non-metallic material

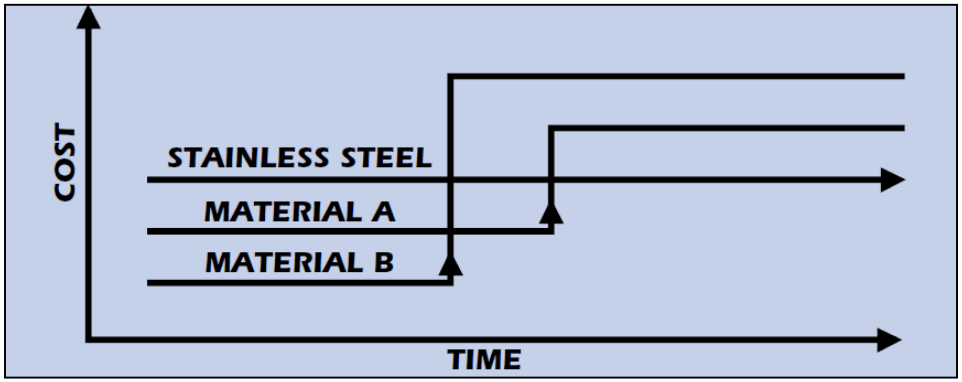


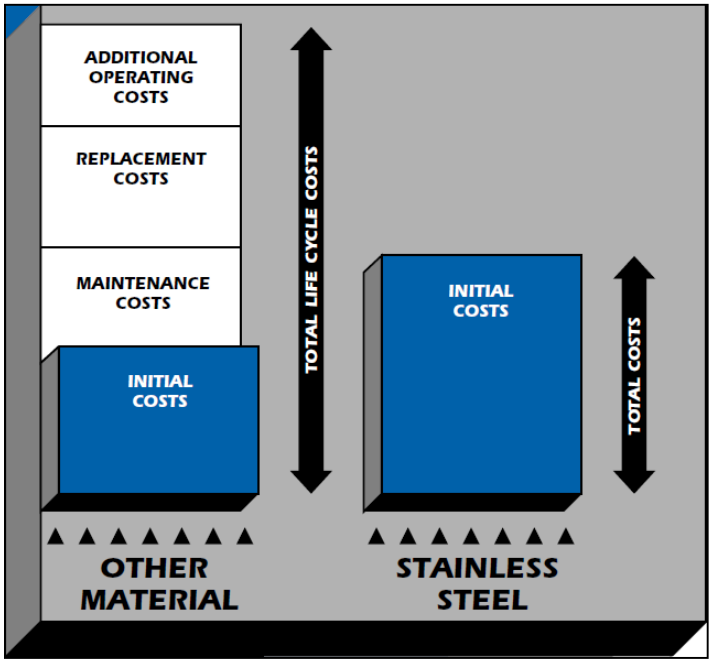
metal

Thin gauge 0,4mm and 0,6mm thick stainless steel sheets are commonly used. Weight: 3,12Kg and 4,68Kg respectively per m^2 only!

Why stainless steel is not expensive if the life cycle cost is taken into account

The cost of structures made of other materials substantially increases over time while the cost of stainless steel structures normally remains constant.





The Cost of corrosion exceeds 137 Billions $ in the USA alone [17]

Life Cycle Cost Comparison of 2 old structures[18,19]

Structures	Completed	Material	Height	Maintenance
Eiffel Tower – Paris * 	1889 	Wrought iron	324m	Every 7 years. Every painting campaign lasts for about a year and a half (15 months). 50 to 60 tons of paint, 25 painters, 1500 brushes, 5000 sanding disks and 1500 sets of work clothes.
Chrysler Building (Roof and Entrance) – New York 	1930 (roof 1929) 	Austenitic Stainless Steel (grade: 302)	319m	Twice in 1951, 1961, 1995. The 1961 cleaning solution is unknown. A mild detergent, degreaser and abrasive was used in 1995.

* The Eiffel tower was built before stainless steel was invented…and it was supposed to be a temporary structure, but the public loved it !

Example:

Comparison of the maintenance of 2 very well known bridges[20, 21]

- Golden Gate Bridge in San Francisco
- Stonecutter's Bridge in Hong Kong

In the next 2 slides

The Golden Gate bridge (1937), San Francisco

<- Maintenance

"a rugged group of **13 ironworkers** and **3 pusher ironworkers** along with and **28 painters**, **5 painter laborers**, and **a chief bridge painter** battle wind, sea air and fog, often suspended high above the Gate, to repair corroding steel. Ironworkers replace corroding steel and rivets with high-strength steel bolts, make small fabrications for use on the Bridge, and assist painters with their rigging. Ironworkers also remove plates and bars to provide access for painters to the interiors of the columns and chords that make up the Bridge. Painters prepare all Bridge surfaces and repaint all corroded areas." [20]

Stonecutter's bridge (2009), Hong Kong

<- Maintenance

Project details : 1,596m-long dual 3-lane high-level cable-stayed bridge, with a clear span of 1,018m. Typhoon resistant.

Material : Stainless Steel EN1.4462 (Duplex) plate with 450MPa yield stress used for the towers above +175m to top (+295m) and for towers skin.

Why stainless rather than C-steel: designed for 120 years life in a hot and polluted seawater environment. Designed for no maintenance. [21]

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Thank you